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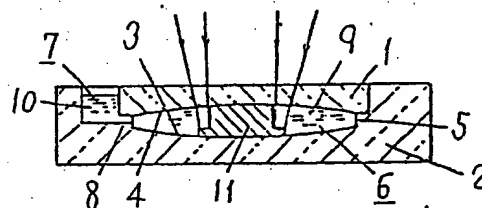
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## 54 Method and apparatus for producing optical element.

57 A plastic optical element with good accuracy and no strain is produced by supplying a mold having a cavity conforming to a shape of the optical element and a feed passage which communicates with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material so that light can pass through said material into the mold cavity, charging a photocurable plastic material through said feed passage into said cavity, irradiating a central part of said cavity with light which initiates a photocuring reaction and enlarging the light in the form of a ring light till the lighted area reaches the periphery of the cavity so as to cure the entire photocurable plastic material, light irradiation being carried out while maintaining a supplementary portion of the photocurable plastic material in said feed passage.

Fig. 3



## Description

### METHOD AND APPARATUS FOR PRODUCING OPTICAL ELEMENT

#### BACKGROUND OF THE INVENTION

##### Field of the Invention

The present invention relates to a method and an apparatus for producing a plastic optical element. More particularly, the present invention relates to a method and an apparatus for producing a plastic optical element comprising polymerization.

##### Description of the Related Art

Plastic lenses are roughly classified into two kinds, one of which is made of thermoplastic polymers. As the thermoplastic polymers, polymethyl methacrylate (PMMA), polycarbonate, polystyrene, acrylonitrile-styrene copolymer and the like are known. These thermoplastic polymer may be molded by compression molding, injection molding or injection-compression molding. In principle, for lens production, the polymer is heated and melt, poured and processed in a mold having a cavity corresponding to the lens shape and compressed with pressurizing the hot polymer so as to compensate a shrunk volume of the polymer which will be caused by cooling through volume elasticity. In the molding of thermoplastic polymer, since heat and pressure are necessary, large molds and apparatuses should be used, and molded articles tend to suffer from minute deformation.

Other lenses which can be produced through polymerization and processing of monomers for thermosetting polymers or thermoplastic polymers such as methyl methacrylate, diethylene glycol bis-allylcarbonate (namely, CR-39), glycol dimethacrylate, diethylene glycol dimethacrylate and the like. The polymers prepared from these monomers generally set at a relatively low temperature under low pressure so that they can be molded by a simple method which is called as casting or cast molding.

Fig. 1 illustrates one of the conventional cast molding methods for producing lenses for spectacles. A pair of glass plates 101, 102 are layered through a gasket 103. A space formed by the the glass plates 101, 102 and the gasket 103 is filled with a liquid monomer 104, and the circumferential edges of the glass plates are clamped with a clip 105. Then, the glass plates containing the monomer therein are kept standing. Since a small amount of a polymerization initiator is added to the monomer just before charging, slight temperature increase initiates a polymerization reaction of the polymer in the space. After several to ten and several hours, the whole monomer is polymerized to give a hard plastic lens. During polymerization, the material in the space shrinks by 10 to 20 %, so that a thickness of the produced lens is decreased.

Although the cast molding can be employed to produce lenses having a relatively uniform and thin thickness such as the spectacle lenses, it is said to be unsuitable for producing lenses for cameras such as VTR cameras. Further, since the cast molding

takes long time, it is not generally accepted for industrial production of the plastic lenses.

To overcome the above drawbacks of the cast molding, Japanese Patent Kokai Publication No. 132221/1980 discloses, as shown in Fig. 2, a method comprising curing a resin 208 in a cavity formed with glass molds 206, 207 while irradiating the resin with a UV light 202, charging an additional amount of a resin 201 from a reservoir 209 through a stop cock 210 into the cavity to fill a gap formed through shrinkage of the cured polymer and removing the molded article after all the resin is cured. Since the UV curing is known as a high rate reaction process, it seems that the combination of this measure with the supplement of the resin would overcome the above drawbacks. However, this method has various problems. For example, since the resin loses its flowability before the entire reaction is completed, the shrunk volume is not sufficiently supplemented. Since the whole reaction proceeds at a high rate, compression stress due to the cure and shrinkage and tensile stress due to reaction against compression stress are quickly generated so that there is no or little time for relaxing stresses, and the stresses exceed breaking stress of the molded article, which results in insufficient accuracy and cracking. Thus, the molded articles are often broken before they are removed from the molds. This is particularly so when the lens has a large thickness.

#### SUMMARY OF THE INVENTION

One object of the present invention is to provide a method for producing a plastic optical element such as a lens with good accuracy at a high rate even in case of the production of a lens having a relatively large difference of thickness.

Another object of the present invention is to provide an apparatus for practicing the process of the present invention.

According to the first aspect of the present invention, there is provided a method for producing a plastic optical element, which comprises supplying a mold having a cavity conforming to a shape of the optical element and a feed passage which communicates with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material so that light can pass through said material into the mold cavity, charging a photocurable plastic material through said feed passage into said cavity, irradiating a central part of said cavity with light which initiates a photocuring reaction and enlarging the light in the form of a ring light till the lighted area reaches the periphery of the cavity so as to cure the entire photocurable plastic material, light irradiation being carried out while maintaining a supplementary portion of the photocurable plastic material in said feed passage.

According to the second aspect of the present invention, there is provided a first embodiment of an

apparatus for producing a plastic optical element, which comprises a mold having a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a ring form light source for emitting light which initiates a photocuring reaction and a variable power lens, wherein said mold, said light source and said variable power lens are so arranged that the center of the ring form light emitted from said light source substantially aligns with the center of the cavity when the light is irradiated on said cavity through said variable power lens.

According to the third aspect of the present invention, there is provided a second embodiment of an apparatus for producing a plastic optical element, which comprises a mold having a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a ring form light source for emitting light which initiates a photocuring reaction and from which light is emitted in a direction towards the axes of the ring form light source and a conical mirror and a lens, wherein said mold, said light source, said mirror and said lens are so arranged that the center of the ring form light which is reflected on the surface of said mirror, passes through said lens and then irradiates said cavity substantially aligns with the center of the cavity.

According to a fourth aspect of the present invention, there is provided a third embodiment of an apparatus of the present invention, which comprises a mold having a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a laser system for generating a laser beam which has a ring form intensity distribution and initiates a photocuring reaction and a variable power lens, wherein said mold, said laser system and said variable power lens are so arranged that the center of the ring form light substantially aligns with the center of the cavity when the laser is irradiated on said cavity through said variable power lens.

According to a fifth aspect of the present invention, there is provided a fourth embodiment of an apparatus of the present invention, which comprises a mold having a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a light source for emitting light which has a strong directivity and initiates a photocuring reaction and a means for irradiating said cavity with said light beam while scanning said beam in a ring form.

In the method of the present invention, the photocurable plastic material contained in the mold cavity is first cured at the center part with light which is irradiated at the center of the cavity. In this step, since the uncured liquid material is still present

around the center part of the plastic material which is being cured, the shrunk volume of the material is supplemented with said uncured liquid material. Then, the liquid plastic material is fed into the cavity through the feed passage in an amount corresponding to the amount which is used for supplementing the shrunk volume. After the reaction in the center part is completed, the irradiated area is expanded in the ring form and in turn, the reaction area is enlarged in the ring form. Around the ring form area in which the plastic material is being cured, there is always the uncured liquid material. Therefore, the shrunk volume is supplemented with the surrounding liquid material. In addition, since no light is irradiated inside the ring form area, excessive reaction which causes strain due to curing is prevented in the inside area. Finally, the ring form light is enlarged to the outermost periphery of the cavity to cure the entire volume of the optical element.

With the first embodiment of the apparatus of the present invention, the ring form light which initiates the photocuring reaction is passed through the variable power lens and the light transmitting material and led into the mold cavity. Through adjustment of the variable power lens, the ring form light can be focused onto the central part or expanded towards the peripheral part of the cavity. Thus, the photocurable plastic material in the mold cavity can be cured from the central part toward the peripheral part step by step, and the shrunk volume can be supplemented with the uncured plastic material through the feed passage.

With the second embodiment of the apparatus of the present invention, the ring form light is reflected on the conical mirror, passed through the lens and then led into the mold cavity through the light transmitting material. Through change of the relative position between the ring form light source and the conical mirror in the direction along the axis which is common to the light source and the mirror, a diameter of the light ring is changed so that the ring form light is focused onto the central part or expanded towards the peripheral part of the cavity. Thus, the photocurable plastic material in the mold cavity can be cured from the central part toward the peripheral part step by step, and the shrunk volume can be supplemented with the uncured plastic material through the feed passage.

With the third embodiment of the apparatus of the present invention, the laser beam having inherently the ring form intensity distribution is passed through the variable power lens and the light transmitting material and then led into the mold cavity. Through adjustment of the variable power lens, the laser beam can be focused onto the central part or expanded towards the peripheral part of the cavity. Thus, the photocurable plastic material in the mold cavity can be cured from the central part toward the peripheral part step by step, and the shrunk volume can be supplemented with the uncured plastic material through the feed passage.

With the fourth embodiment of the apparatus of the present invention, the light beam which has the strong directivity and initiates the photocuring

reaction irradiates the mold cavity through the light transmitting material. Since the light beam is scanned in the ring form in the cavity, if the light beam is scanned at a rate faster enough than the cure rate of the plastic material, it achieves the same effect as the ring form laser beam or light. Thus, when the light beam is scanned from the center to the periphery of the cavity, the photocurable plastic material in the mold cavity is cured from the central part toward the peripheral part, and the shrunk volume can be supplemented with the uncured plastic material through the feed passage.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates one of the conventional cast molding methods for producing lenses for spectacles,

Fig. 2 illustrates a method for producing a plastic lens disclosed in Japanese Patent Kokai Publication No. 132221/1980,

Fig. 3 is a cross sectional view of a mold for use in the production of a plastic lens according to the present invention,

Fig. 4 is an enlarged cross sectional view of a part of the mold of Fig. 1 in an initial photopolymerization stage,

Fig. 5 is a partial view of Fig. 4,

Fig. 6 is another partial view of Fig. 5,

Fig. 7 shows the transmittances the plastic materials and the photopolymerization initiators,

Fig. 8 shows a curing pattern of the plastic material in the mold,

Fig. 9 shows other irradiation pattern of the plastic material in the mold,

Fig. 10 is a partial cross sectional view of another embodiment of the apparatus of the present invention,

Fig. 11 is a cross sectional view of one of the light sources to be used in the apparatus of the present invention, and

Figs. 12, 13, 14 and 15 are cross sectional views of various embodiments of the apparatus of the present invention.

#### DETAILED DESCRIPTION OF THE DRAWINGS

The present invention will be illustrated by making reference to the accompanying drawings by way of example.

Fig. 3 is a cross sectional view of a mold for use in the production of a plastic lens according to the present invention. On inner surfaces of an upper mold 1 made of quartz glass and a lower mold 2, lens surfaces 3,4 are so formed that their curvatures correspond to those of surfaces of a lens to be produced. The upper mold 1 is engaged with the lower mold 2 in which a step 5 is formed for adjusting the lens thickness. The lens surfaces 3,4 and the step 5 define a cavity 6 which corresponds to the outer shape of the lens. In the lower mold 2, a feed passage 7, which communicates with the cavity 6, is formed through a dent portion 8 formed in a part of the step 5.

In Fig. 3, a photocurable plastic material 9 is

already charged in the cavity 6, and an additional amount 10 of the plastic material is contained in the feed passage 7.

The "photocurable plastic material" herein used is intended to mean a mixture of a photopolymerizable monomer and a photopolymerization initiator, which mixture is in a liquid state in a temperature range in which the polymerization does not proceed quickly. Preferably, the photopolymerizable monomer is an ethylenically unsaturated compound or a mixture of two or more ethylenically unsaturated compounds. Examples of the ethylenically unsaturated compounds are acrylates (e.g. 2-hydroxyethyl acrylate, ethylene glycol diacrylate, phenoxyethyl acrylate, phenoxydiethylene glycol acrylate, 2-hydroxy-3-phenoxypropyl acrylate, tetrahydrofurfuryl acrylate, dicyclopentenloxyethyl acrylate, 1,4-butanediol diacrylate, neopentyl glycol diacrylate, triethylene glycol diacrylate, etc.), methacrylates (e.g. 2-hydroxyethyl methacrylate, glycidyl methacrylate, bisphenol-A dimethacrylate, cyclohexyl methacrylate, dicyclopentenyl methacrylate, monobromodichloropentenyl methacrylate, 2,2-bis(4-methacryloxy-3,5-dibromophenyl)propane, bis(oxyethyl)-tricyclo[5.2.1.0<sup>2,6</sup>]decane dimethacrylate, thiobisphenol dimethacrylate, etc.) and aromatic vinyl compounds (e.g. styrene, divinylbenzene, etc.). They may be used independently or as a mixture thereof. Examples of the photopolymerization initiators are benzoin methyl ether, benzoin ethyl ether, benzyl dimethyl ketal, 1-hydroxycyclohexyl phenyl ketone, 1-hydroxy-2-methyl-1-phenylpropanone, diethoxyacetophenone, trichloroacetophenone and the like. They may be used independently or as a mixture thereof.

In the hatched part 11 in Fig. 3, the material 9 has been cured, and in a part irradiated by the ring form light indicated by arrows, the material 9 is being cured.

Fig. 4 is an enlarged cross sectional view of a part of the mold of Fig. 3 in an initial photopolymerization stage. The light focused in a spot is irradiated at the center of the cavity. In a height direction, substantially the middle height is in the highest energy state since the light beams indicated by the arrows are most concentrated at the middle height. Therefore, at that height, the polymerization proceeds most vigorously. By moving up and down a position at which the light beams are most concentrated, the photopolymerization reaction is controlled in the height direction.

Fig. 5 is a partial view of Fig. 4, and shows a state in which a short period of time passes from the state of Fig. 4. That is, the position at which the light beams are most concentrated is shifted upwardly near to the lens surface 3 of the upper mold 1. When the material 9 near the lens surface 3 is cured, a narrow gap 8 is formed between the already cured material 11 and the lens surface 3. As soon as the gap is formed, a portion of the uncured material 9 flows into said gap through the capillary phenomenon and cured. Thus, no strain due to shrinkage of the material caused by curing is generated so that the shape of the mold is accurately transferred.

Fig. 6 is another partial view of Fig. 4, and shows a

state in which the time further passes from the state of Fig. 5. At this stage, the ring form light is irradiated around the already cured part 11. At a part 12 which is newly cured, its periphery tends to shrink to a size shown by dotted lines. But, the shrunk volume is easily supplemented with the uncured material 9.

In the above description, the plastic material is cured from the lower mold surface to the upper mold surface according to the lighting pattern at the central part, and then the ring form part surrounding the central part is cured from the lower mold surface to the upper mold surface. But, the cured part does not necessarily have such a clear outline as in the drawings, since the curing rate has a gentle slope because of a distribution of light intensity, light scattering in the liquid material, micro-Brownian motion of optically decomposed radicals in the liquid material and the like. The reaction in the vertical direction often proceeds simultaneously at any part in this direction unless the light has a very large concentration angle. In such cases, the shrunk volume can be supplemented with the uncured plastic material according to the principle of the present invention.

As the light source, one generating light having a wavelength of 300 to 450 nanometers such as a high pressure mercury lamp, a metal halide lamp, a He-Cd laser and an Ar ion laser are preferred.

In general, the plastic material has poor transmission in a wavelength range shorter than 400 nanometers as shown with the curve C of Fig. 7. On the contrary, some of the photopolymerization initiators have a light absorption and decomposition peak at a wavelength longer than 400 nanometers (for example, the peak "a" in the curve A of Fig. 7) and some of the photopolymerization initiators have said peak at a wavelength shorter than 400 nanometers (for example, the peak "b" in the curve B of Fig. 7). The above described embodiment of the present invention is suitable for the combination of the plastic material having the transmittance of the curve C and the photopolymerization initiator having the transmittance of the curve B.

Since most of the photopolymerization initiators have the light absorption peak at a wavelength shorter than 400 nanometers, the illuminated light is absorbed with the plastic material so that the illumination effect decreases as the thickness of the plastic material layer increases. In such case, the curing proceeds as shown in Fig. 8 which schematically shows a curing pattern. Through the already cured part 13, the light is illuminated as indicated by arrows, and the curing reaction proceeds in the direction in which the light is illuminated. In Fig. 8, 14 stands for the upper mold, 15 stands for the lower mold and 16 stands for the uncured plastic material.

In this embodiment, illumination from both sides of the molds as shown in Fig. 9 is effective in view of the curing rate and prevention of the curing strain. In Fig. 9, the arrows indicate the light illumination from the both sides, 17 stands for the upper mold, 18 stands for the lower mold, 19 stands for the uncured plastic material, 20 stands for the feed communicating with the feed passage and 21 stands for the already cured part of the plastic material.

Fig. 10 schematically shows one embodiment of the apparatus for producing the plastic lens according to the present invention. A mold 22 is used for producing a concave lens and has substantially the same structure as the mold of Fig. 3. Around a ring form high pressure mercury lamp 23, provided is a ring form reflector 24 having a parabolic cross section. Below the open side of the reflector, a ring form lens 25 is provided. Further below the lens 25, provided are vertically movable variable power lenses 26 and also a fixed lens 27 which images the ring form light on the mold 22. The centers of the lamp 23, the reflector 24 and the lenses 25, 26 and 27 substantially align with each other. The lens 25 has a doughnut shape which corresponds to a peripheral portion of a convex lens. In Fig. 10, an imaginary central portion of the convex lens is indicated with an alternate long and two short dashes line. Thus, the lens 25 substantially acts as a convex lens and can focus a parallel light beam of the ring form which is generated with the high pressure mercury lamp 23 and the reflector 24 on the optical axis. The variable power lenses 26 modify a focus angle of the light which has been focused with the lens 25 so that, after passing through the lens 27, the light forms an image on the cavity 28 of the mold 22. In addition, the variable power lenses 26 change a radius of the formed ring form pattern of the irradiated light through moving up and down the lens 25. That is, in Fig. 10, the lenses 26 are positioned at an intermediate height. When the variable power lenses 26 are shifted upwardly to the upper limit position A, the upper surface 29 of the lenses 26 reaches the dashed line 29, so that the light beam indicated with the dashed lines illuminates the outermost part of the cavity 28 of the mold 22. When the variable power lenses 26 are lowered to the lower limit position B, the light beam is condensed to form a point-like light. Thus, at the start of the molding, the variable power lenses 26 are positioned at the lower limit position B, and then the lenses 26 are shifted up as the photopolymerization proceeds to enlarge the diameter of the ring form light pattern, whereby the plastic material in the mold cavity can be thoroughly cured from the center to the periphery of the mold. The lens 27 can focus the light in the cavity through vertical movement thereof. When the cavity 28 has a large depth, the lens 27 is preferably vibrated vertically. In Fig. 10, 31 stands for the feed passage.

Fig. 11 illustrates another embodiment of the light source to be used in the apparatus for producing the plastic lens according to the present invention, in which a small mercury lamp 32 which is similar to a point light source instead of the ring form high pressure mercury lamp 23 in Fig. 10. Below the mercury lamp 32, provided is a quartz glass plate 33 in which a chromium metal layer 34 is deposited so as to form a ring form transparent part through which the light passes. The light passing the ring form transparent part on the quartz glass plate 33 forms a ring form light beam, which can be shrunk or enlarged and then irradiated on the plastic material in the mold in the same manner as in Fig. 10. Such light source is economical and easily set up.

Fig. 12 shows a further embodiment of the

apparatus for producing the plastic lens. The light source consists of a ring form high pressure mercury lamp 36, a ring form mirror 37 and a ring form lens 38 and generates substantially parallel light beams in the direction towards the center of the ring as shown by the solid lines. A conical mirror 39 has an apex angle of about  $90^\circ$  and is positioned concentrically with the ring form lamp 36. The light beams are reflected on the surface of the conical mirror 36 in the downward direction. Then, through a Fresnel lens 40 which acts as a convex lens, the light is focused on a cavity 42 of a mold 41. When the cavity has a large depth, the Fresnel lens 42 is moved up and down to shift the focal point in the depth direction. In Fig. 12, 43, 44 and 45 stand for the upper mold, the lower mold and the feed passage. The light source and the conical mirror can be relatively moved in the axial direction. When the light source is lowered, the light beams pass along the broken lines in Fig. 12. That is, when the light source moves towards the mold, the light beams are reflected near the apex of the conical mirror 39 so that the radius of the ring form light is decreased. Thus, at the start of the molding, the relative position of the light source with the mirror 39 is so adjusted that the light beams are reflected on the mirror surface near the apex of the conical mirror 39 and, as the photopolymerization proceeds, the light source and/or the conical mirror are relatively moved so that the light beams are reflected on the mirror surface apart from the apex of the conical mirror 39 so as to increase the radius of the ring form light to be irradiated on the plastic material in the mold cavity.

In this apparatus of Fig. 12, since no variable power lens is required, the apparatus can be made simple and compact.

Fig. 13 shows a yet another embodiment of the apparatus for producing the plastic lens according to the present invention.

A He-Cd laser system 46 can generate a laser beam having an intensity distribution as shown by the alternate long and two short dashes line 47. The relative positions among the laser system 46, a lens 48 and a mold 49 are adjusted so that the circular peak of the laser beam intensity distribution is enlarged at the irradiated position in the mold cavity through the function of the lens 48 which enlarges the laser beam. For this end, the lens 48 is vertically movable. When the lens 48 is lowered to the position shown by the dashed line 48', the laser beam is focused at a central point in the cavity 50. Thus, it is possible to irradiate the plastic material in the cavity 50 while enlarging the ring form laser from the center to the periphery of the mold.

Fig. 14 shows a yet further embodiment of the apparatus for producing the plastic lens according to the present invention. A He-Cd laser system 51 is provided so that a laser beam 56 irradiates a cavity 53 of a mold 52. The mold 52 is fixed on the X-Y table 55 which is freely moved in the horizontal directions with a control apparatus (not shown). In this embodiment, the table 55 is so moved that the cavity is rotated around its center, whereby the laser beam is circularly irradiated on the cavity. When the cavity is rotated quickly enough in comparison to the

photopolymerization rate, the laser beam seems to be irradiated as if it were generated with the ring form light source. As the distance between the irradiated position and the center of the cavity is increased, the same effect is achieved as in the case where the diameter of ring form light is increased. In Fig. 14, 57 and 58 stand for the upper and lower molds, respectively, the crosshatched part 59 is the cured material, and 60 stands for the feed passage.

Fig. 15 is a further embodiment of the apparatus for producing the plastic lens according to the present invention. A laser beam 62 generated with a He-Cd laser system 61 is reflected on a surface of a mirror 65. A mounting angle  $\theta$  of the mirror 65 on a rotating axis 64 can be adjusted. By enlarging the mounting angle  $\theta$  from the angle at which the laser beam is irradiated at the center of the cavity 67 of the mold 66, the irradiated position shifts from the center to the periphery of the mold cavity. When the mirror is rotated around the rotating axis quickly enough in comparison with the photopolymerization rate, a substantially ring form light is formed on the cavity and its diameter is increased from the center to the periphery of the cavity. In Fig. 15, 68, 69 and 70 stand for the upper mold, the lower mold and the feed passage.

When the laser beam is used as in the embodiments of Figs. 14 and 15, the reaction area is precisely controlled since the laser beam has strong directivity. In combination with means for scanning the laser beam in the ring form such as the X-Y table 54 in Fig. 14 and the mirror 65 in Fig. 15, the radius of the irradiated area can be enlarged step by step, whereby the plastic lens with less strain can be produced. Further, in the embodiments of Figs. 14 and 15, no condenser lens is used.

According to the present invention, since the plastic lens is produced under conditions under which the strain in the mold is suppressed and the reaction proceeds as quickly as possible, the curing of the plastic material is not always completed in view of the polymerization degree. In such case, the plastic lens is gradually heated to complete the curing through thermal polymerization, or it is further irradiated with light to complete the curing so as to accurately improve the characteristics of the lens.

## Claims

1. A method for producing a plastic optical element, which comprises supplying a mold having a cavity conforming to a shape of the optical element and a feed passage which communicates with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material so that light can pass through said material into the mold cavity, charging a photocurable plastic material through said feed passage into said cavity, irradiating a central part of said cavity with light which initiates a photocuring reaction and enlarging the light in



the form of a ring light till the lighted area reaches the periphery of the cavity so as to cure the entire photocurable plastic material, light irradiation being carried out while maintaining a supplementary portion of the photocurable plastic material in said feed passage.

2. An apparatus for producing a plastic optical element, which comprises a mold having a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a ring form light source for emitting light which initiates a photocuring reaction and a variable power lens, wherein said mold, said light source and said variable power lens are so arranged that the center of the ring form light emitted from said light source substantially aligns with the center of the cavity when the light is irradiated on said cavity through said variable power lens.

3. The apparatus according to claim 2, wherein the light source comprises a laser system which generates a laser beam having a ring form intensity distribution.

4. An apparatus for producing a plastic optical element, which comprises a mold having

a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a ring form light source for emitting light which initiates a photocuring reaction and from which light is emitted in a direction towards the axes of the ring form light source and a conical mirror and a lens, wherein said mold, said light source, said mirror and said lens are so arranged that the center of the ring form light which is reflected on the surface of said mirror, passes through said lens and then irradiates said cavity substantially aligns with the center of the cavity.

5. An apparatus for producing a plastic optical element, which comprises a mold having a cavity conforming to a shape of the optical element and a feed passage which communicate with said cavity, at least one side of which mold for forming one surface of the optical element is made of a light transmitting material, a light source for emitting light which has a strong directivity and initiates a photocuring reaction and a means for irradiating said cavity with said light beam while scanning said beam in a ring form.

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Fig. 1

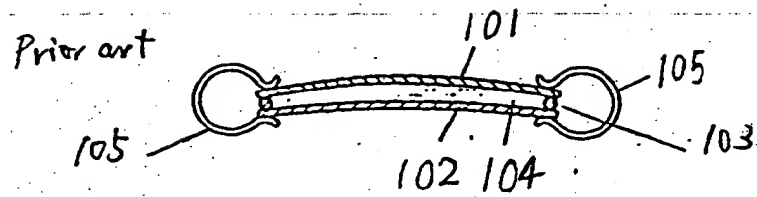


Fig. 2

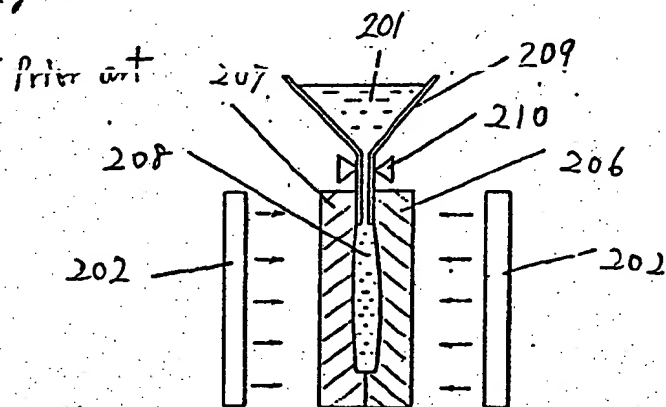


Fig. 14

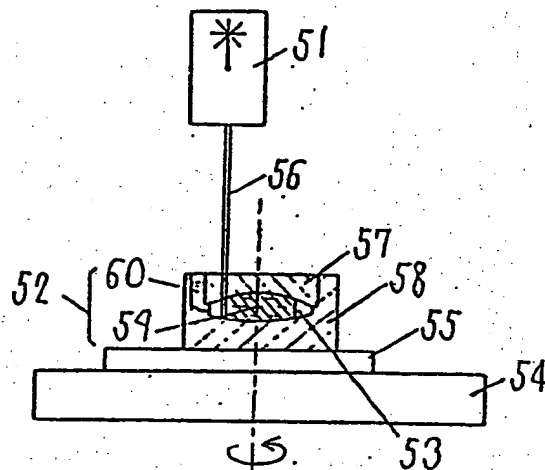


Fig. 15

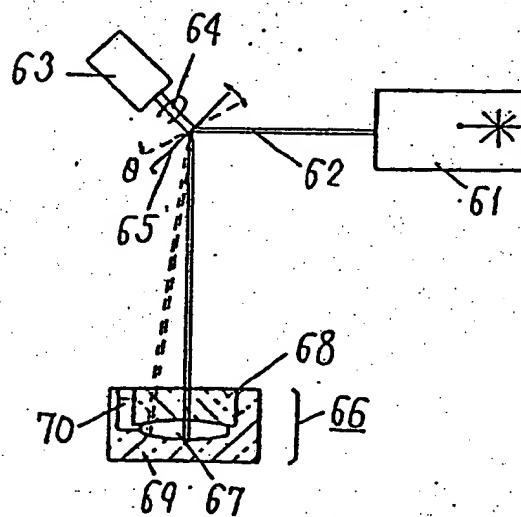


Fig. 3

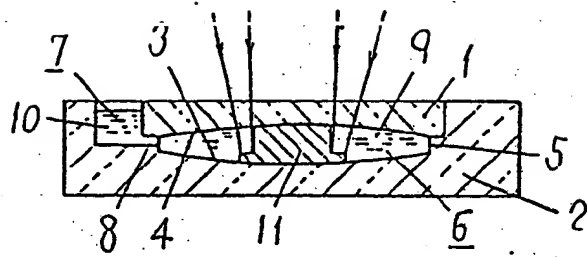


Fig. 4

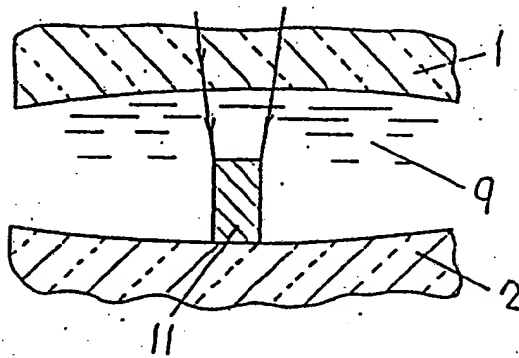


Fig. 5

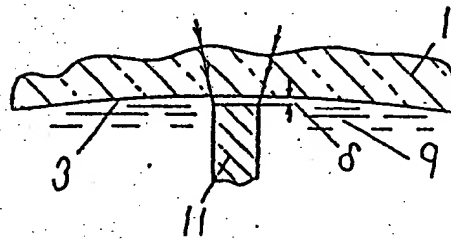


Fig. 6

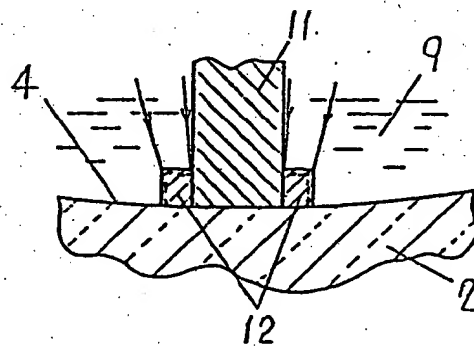


Fig. 7

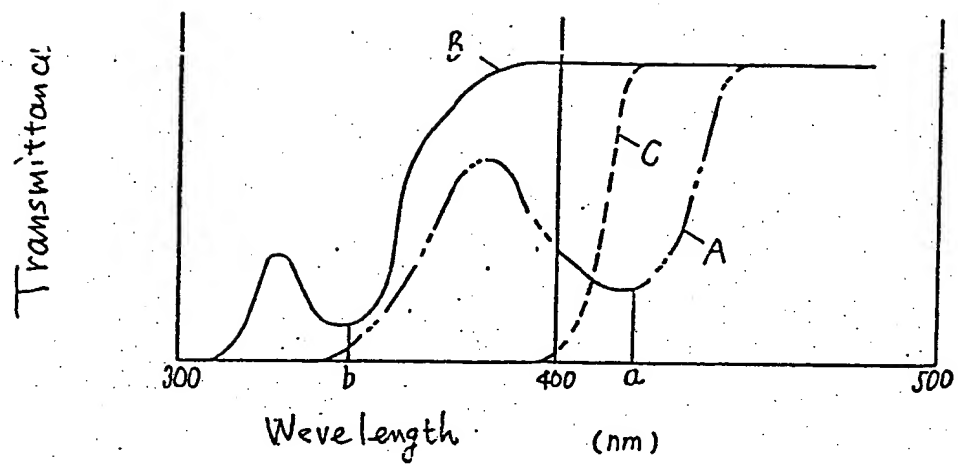


Fig. 8

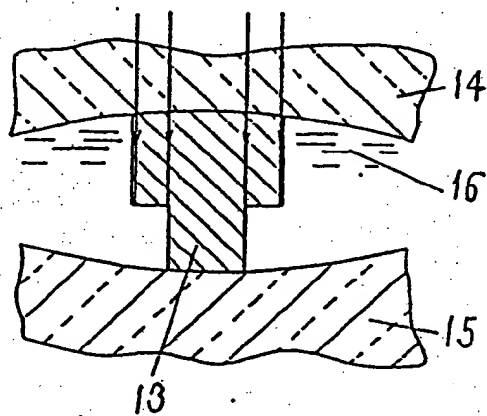


Fig. 9

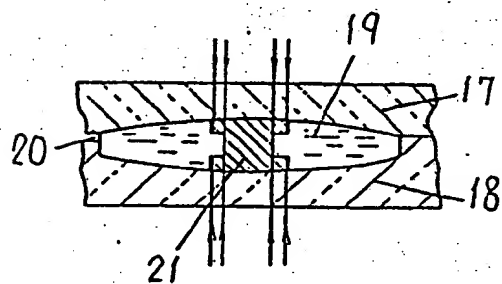


Fig. 10

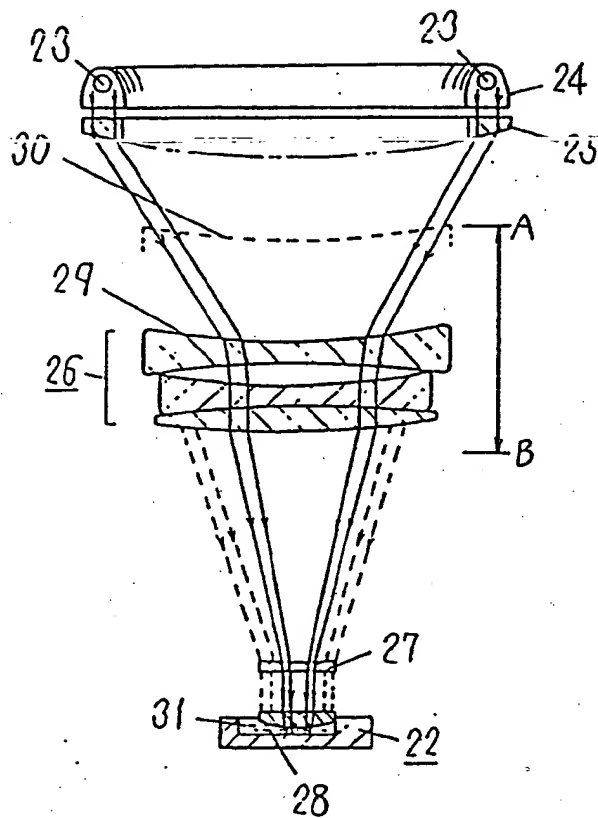


Fig. 11

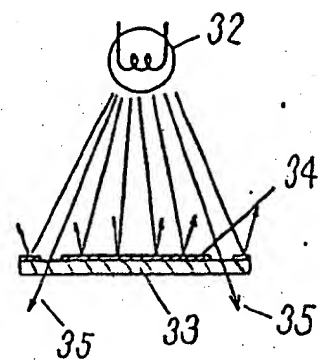


Fig. 12

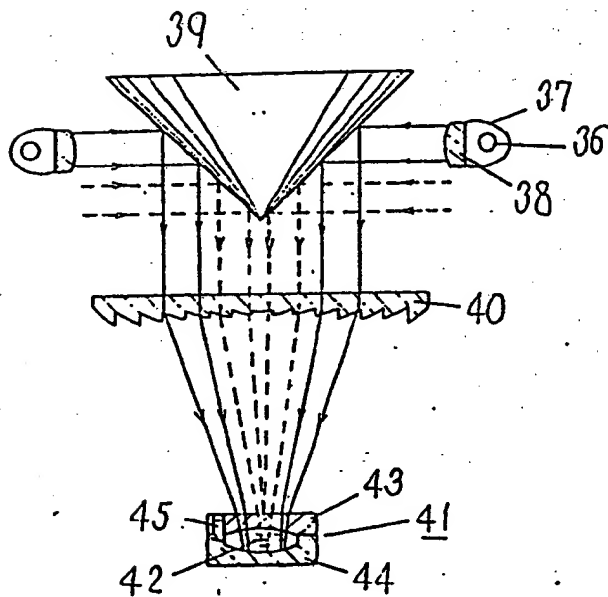
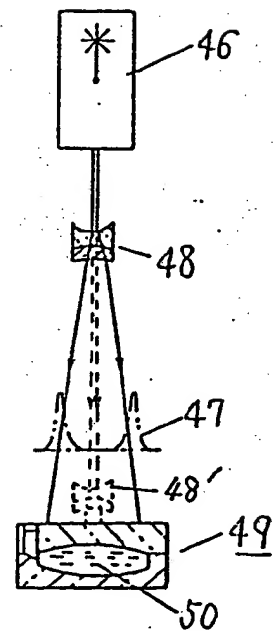


Fig. 13



⑫

# **EUROPEAN PATENT APPLICATION**

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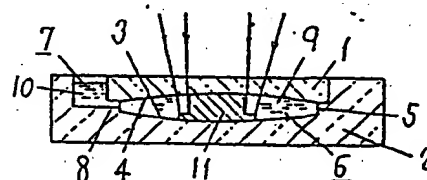
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## ⑸ Method and apparatus for producing optical element.

⑹ A plastic optical element with good accuracy and no strain is produced by supplying a mold (1, 2) having a cavity (6) conforming to a shape of the optical element and a feed passage (7) which communicates with said cavity, at least one side (1) of which mold for forming one surface of the optical element is made of a light transmitting material so that light can pass through said material into the mold cavity, charging a photocurable plastic material through said feed passage (7) into said cavity, irradiating a central part (11) of said cavity with light which initiates a photocuring reaction and enlarging the light in the form of a ring light till the lighted area reaches the periphery of the cavity so as to cure the entire photocurable plastic material, light irradiation being carried out while maintaining a supplementary portion (10) of the photocurable plastic material in said feed passage.

Fig. 3





European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number

EP 88 73 0282

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	PATENT ABSTRACTS OF JAPAN, vol. 7, no. 124 (M-218)[1269], 28th May 1983; & JP-A-58 42 436 (MATSUSHITA DENKI SANGYO K.K.) 11-03-1983 * Abstract *	1-5	B 29 D 11/00 B 29 C 37/00
D,Y	PATENT ABSTRACTS OF JAPAN, vol. 4, no. 187 (M-48)[669], 23rd December 1980; & JP-A-55 132 221 (MATSUSHITA DENKI SANGYO K.K.) 14-10-1980 * Abstract *	1-5	
Y	EP-A-0 226 123 (MATSUSHITA DENKI) * Page 18, line 25 - page 19, line 3 *	1-5	
Y	US-A-4 701 005 (M. NOGUCHI)	2	
Y	EP-A-0 204 378 (POLYGRAM) * Column 5, lines 44-53; figure 9 *	3	
Y	US-A-3 242 806 (HINE)	4	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US-A-4 166 088 (NEETE)		B 29 D B 29 C G 02 B
A	US-A-4 022 855 (HAMBLIN)		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 31-08-1989	Examiner ROBERTS P.J.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			